I had my fuel cell car's front wheels at the starting line.  Suddenly Adam, one of my three chemical engineering counselors, shouted, “Go!" I released my car, and it jolted forward towards the finish line. But after a couple of feet it started curving towards the right side of the track. I quickly maneuvered to the right side of my car, while I kept an eye on my car to make sure I wasn't blocking any sunlight from reaching the solar panel. As I bent over and nudged my car to the left, somebody behind me said "Watch out! You almost blocked the sunlight!" I mumbled "Sorry" and stepped to the left of my car. Luckily, I didn't have to try and correct my car's direction again. But keeping the steering perfectly straight so that you don't waste energy or speed was just one of the many challenges to tuning my car.

Some things couldn't be helped, like a cloud covering half the track, or a badly super-glued wheel. But most of the differences could be fixed.

One challenge to making the car run efficiently was how the car was shaped. It's a rather boxy-ish vehicle with the engine and solar panel in the front, the hydrogen fuel cell in the middle, and the water/hydrogen/oxygen tanks in the back. The fuel cell I am using in this kit is a reversible PEM fuel cell. The abbreviation PEM refers to the membrane that separates the oxygen side from the hydrogen side of the cell. The letters “PEM” stand for Proton Exchange Membrane. A reversible fuel cell means it can run both ways, using hydrogen and oxygen to make electricity and water, or it can be used in electrolysis to make hydrogen and oxygen. There are two electrical contact plates in the fuel cell, one on each side of the PEM. The plates have different names because they accomplish different tasks. The plate on the hydrogen side is called the anode, and the plate on the oxygen side is called the cathode. On the anode, electrically neutral hydrogen molecules from the hydrogen tank are oxidized via electron donation into hydrogen ions. These positively charged hydrogen ions diffuse through the PEM towards the negatively charged cathode. The PEM will allow the hydrogen ions through, but the larger oxygen ions cannot fit, so the current of exchange can only go one way. On the cathode the hydrogen ions react with the oxygen and the electrons that the hydrogen gave up earlier. The way we use this process is by putting whatever we want to run with the electricity between the external connection of the anode and cathode. In the case of my fuel cell car, the electricity was used to power the motor.

My gripe about the design is how the solar panel is hinged to the car. The solar panel can move from horizontal to about 60 degrees facing forward. This limits the solar panel angles to catch sunlight so the car has to be facing the sun, or be out during mid-day. The time of day that our class went outside for the solar panel was not mid-day. Also our track for running the cars on was a slightly sloped brick pathway, and the sun was on the uphill side. So our class was trying which way to face for our test runs: uphill with good sunlight or downhill and try and collect sunlight with our solar panels flat. While everybody else was debating over our predicament, I put my mind to the problem and came up with a solution. I flipped the + and - wires for the motor; that way my engine would power my car downhill and face the solar panel towards the sun. In other words, I would drive my car backwards. Unfortunately, while I was testing my brilliant idea, they set up the start and finish so we would be going uphill. Oh well, sometimes genius isn't appreciated.

As I mentioned before, the track is a bunch of laid bricks with lots of bumps and ruts. When we were conducting our fuel-cell races, some cars would stop for what seemed to be no reason. But I found out what I am sure was the cause of the problem. This problem can affect the fuel cell's performance to the point of the fuel cell not working, but first you need to know how the fuel cell works. This type of fuel cell has a small near flat chamber on both sides of a special piece of plastic. This special plastic will only let through protons when it's wet, so there has to be some water in the chambers. The hydrogen molecules will release some electrons to travel (through my circuit) to the oxygen side. The now positive hydrogen ions are attracted to the negative oxygen molecules. The ions travel through the plastic membrane to the oxygen side where they react with the oxygen to form water.

Slowly the membrane will fill with water, and then there won't be any room for the hydrogen and oxygen to react. So some people would have full tanks of oxygen and hydrogen, but their fuel cell would be mostly filled with water. So after they had run the fuel cell for a bit and made a little water, there wouldn't be any room for their hydrogen and oxygen. And they would wonder why their fuel cell stopped working.

As I discovered, to get the best performance, you want as little water as possible in the fuel cell, but still enough so that the membrane will let the ions through.

Another challenging problem was trying to seal the tops of the hydrogen and oxygen tanks. The tanks had a hole at the top where you insert the tube that leads to the fuel cell. The tube made a rather poor seal with the tank, so most of the hydrogen or oxygen that I had labored to convert would escape out the top. My class's solution was to put scotch tape around the tube and the top of the tank. This worked well enough for the first day, but since we made our hydrogen and oxygen by splitting water, the tape would get wet. And scotch tape in my experience doesn't hold up well when it's wet. So after a couple of refills, we noticed that our tanks were leaking again.

Luckily, one of our counselors found some duct-tape so we all re-taped our tanks. Unfortunately for us, nothing would stick to those tubes, not even duct tape! Some people thought we should glue the connection shut, but we couldn't do that because we need to be able to move the tubes. So the solution was to re-tape the tanks each day.

On Friday our parents came to watch us demonstrate what we had been learning all week. We got to bring our cars out and charge them using the solar panel. Our leaders told us to explain to our parents what we were doing with our fuel cell cars. So while I talked, I kept running water through the fuel cell to get maximum conversion. After we filled the tanks Adam lined up six of my classmates to run the first heat. I watched the first two heats, and then in the third and final heat of the first round I set my car on the far left of the track. Adam yelled "GO!" and I released my car; it got stuck in a rut and I pushed it out again. But then my car bumped another guy's car and his pushed ahead! We were near the end of the race track, and my vehicle managed to pull into third place. But I wondered why my car didn't run faster. I realized later that I had made the same mistake others had made when I was fueling my car - I left too much water in the fuel cell so it didn't produce as much power. Unfortunately, I didn't place high in any of the other races, but that doesn't bother me, because I know I just didn't tweak the car quite right.

- David Johnson, June 2006